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Novel Parametric-effect MEMS Amplifiers/Transducers for Sonar Applications

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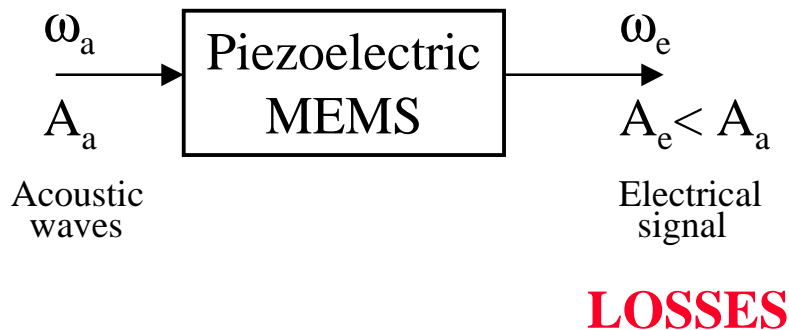
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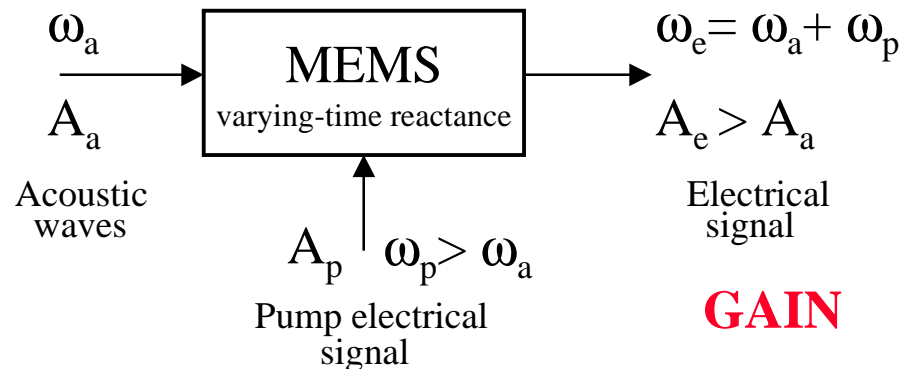
Idea: Use Parametric Effects in MEMS



Transducer



Parametric Amplifier Transducer



First mechanical parametric amplifier using MEMS

- Advantages:
- gain at the transducer level
 - low-noise (no 1/f noise)
 - silicon technology: high integration, low cost
 - wide bandwidth (kHz - MHz)



Parametric Effects



- have been largely used in **1960's**: up and down frequency conversion, amplification **at microwave frequencies**.
- are based on **time varying properties** of a capacitor or inductor (Manley-Rowe Equations).
- allow to **transfer power** from the pump frequency (ω_p) to the input signal frequency (ω_s) or to the up-conversion frequency (ω_u) \Rightarrow **GAIN**.
- The source of power for a usual transducer amplifier is a **dc supply**,
for a parametric amplifier: the **source of power is the pump electrical signal (ω_p), which is a higher frequency** than the input signal (ω_s) .



Amplifiers / up-converters

Gain - Bandwidth



Time varying capacitor: $C(t) = C_0 + C_1 \cdot \cos(\omega_p t) + C_2 \cdot \cos(2\omega_p t) + \dots$ with $C_1/C_0 = 0.5 - 1.0$

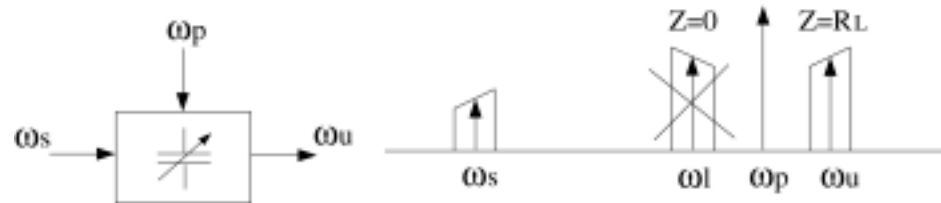
⇒ currents and voltages are generated at all **combination frequencies**:

$$f_{n,m} = n \cdot f_s \pm m \cdot f_p \quad (n, m = -\infty \dots \infty)$$

Practically, we will keep only certain combinations of frequencies.

Noninverting up-converter

$$f_u = f_p + f_s$$



Equivalent input conductance is positive

⇒ **Stable** amplifier and possible matching

Max. gain and bandwidth at matched conditions:

$$g_u = g_s = 2\pi C_1 \cdot \sqrt{f_s \cdot (f_p + f_s)}$$

Manley and Rowe: $\frac{P_s}{f_s} + \frac{P_u}{f_u} = 0$

Transducer and Power Gain: $\frac{P_u}{P_s} = \frac{f_p + f_s}{f_s} > 1$

Bandwidth: $B = \frac{C_1}{C_0} \cdot \sqrt{2 \cdot f_s \cdot (f_p + f_s)}$